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# Real-time VLBI Network with 10GbE Connection, OCTAVE

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**Abstract**

The Japanese real-time VLBI network OCTAVE (Optically Connected Array for VLBI Exploration) has been developed to increase sensitivity by expanding bandwidth with optical fiber links. Four stations are connected to real-time correlators with dedicated 10GbE/STM-16 modules via an academic network, a test bed network, and local access networks. The real-time correlation is useful to increase operational efficiency without media transportation. Disk storage modules have also been developed to connect stations without optical fiber link for special non-real-time observations.

## 1. Introduction

Bandwidth is one of the most important parameters which define sensitivity of interferometric observation. The bandwidth has been limited by the recording rate of the data storage in many arrays. Data transmission by optical fibers can break the limitation of bandwidth. The OCTAVE (Optically Connected Array for VLBI Exploration) project connects wide-band data of radio telescopes to a correlator by optical fibers. Currently more than four telescopes are connected by an academic communication network, a test bed network, and local access lines. The observation system of OCTAVE is described in this paper.

## 2. Observation

The OCTAVE VLBI network consists of eight radio telescopes with large diameters in Japan. The four stations of Yamaguchi University, Gifu University, Tsukuba/GSI, and Hokkaido University are connected by optical fibers. Connection to the Ibaraki telescopes by optical fibers are planned and proceeding. On the other hand, the Nobeyama and Usuda telescopes are currently not connected by optical fibers. Therefore data recording at the sites and transport are required in order to join the OCTAVE observations. OCTADISKs (OCTAve DISK modules) which are based on a disk buffer developed for KJJVC (Korean Japan Joint VLBI Correlator) are used for recording data.

OCTAVE provides wide band observations at a rate of more than 2 Gbps for high sensitivity observations. Doi [1] showed that the OCTAVE network provided good VLBI data for studying radio-loud broad absorption line (BAL) quasars. Takaba [2] also showed that the geodetic observations contribute geodetic delay estimation. Because OCTAVE is operated as a sub-array of JVN (Japanese VLBI Network), proposals for OCTAVE observations are evaluated and judged by JVN [3]. The list of telescopes and observation specifications are summarized in Table 1.

Table 1. OCTAVE telescopes. Nobeyama and Usuda are connected by data transportations. The connections to the Ibaraki telescopes are now under way.

| **Stations** | **Diameter** | **Observing bands** | **Bitrate x ch** |
|---|---|---|---|
| Yamaguchi University / NAOJ | 32 m | K, X | 2Gbps x 2 |
| Gifu University | 11 m | K | 2Gbps x 2 |
| GSI, Tsukuba | 32 m | K, X | 2Gbps x 2 |
| Hokkaido University | 11 m | K, X | 2Gbps x 1 |
| Ibaraki University / NAOJ | 32 m | K, X | 2Gbps x 2 |
| NICT, Kashima | 34 m | Q, K, X | 2Gbps x 2 |
| NAOJ, Nobeyama | 45 m | Q, K | 2Gbps x 1 |
| JAXA, Usuda | 64 m | X | 2Gbps x 2 |

## 3. Network

SINET4 is the academic network operated by National Institute of Informatics, NII. Nodes of SINET4 in Universities and national institutes are connected by optical fibers. The correlators of OCTAVE are connected to the SINET4 node at National Astronomical Observatory of Japan (NAOJ) at a rate of 20 Gbps. The Tsukuba 32-m, Yamaguchi 32-m, Gifu 11-m, and Hokkaido 11-m telescopes are connected to SINET4 nodes at a rate of 10 Gbps through local access lines. The SINET4 connections are provided by reservation in advance as L1OD (Layer 1 On Demand) to time-share communications resources with other users.

JGN-X (Japan Gigabit Network eXtreme) is the test bed network of National Institute of Information and Communications Technology, NICT, following the project of JGN2+. The Kashima 34-m telescope is connected to Koganei, the headquarters of NICT, with 10GbE. The telescopes at Ibaraki are going to be connected to JGN-X via local access lines at the Kashima 34-m site.

GEMNET2 is also a test bed network which has mainly been used to verify and demonstrate new technologies operated by NTT Laboratory. Connection of 2 Gbps (STM 16) - 2ch between Koganei and NAOJ is provided by GEMNET2 by using WDM (Wavelength Division Multiplexing) and ATM switching technologies. The Usuda 64-m and the Nobeyama 45-m telescopes had been connected to NAOJ by GEMNET2 from 2002 to 2007. Because the connection is suspended now, data transport by HDD recorders enables them to join OCTAVE observation.

## 4. Hardware

One of the features of OCTAVE is real-time correlation. Several dedicated modules have been developed to realize the real-time correlation.

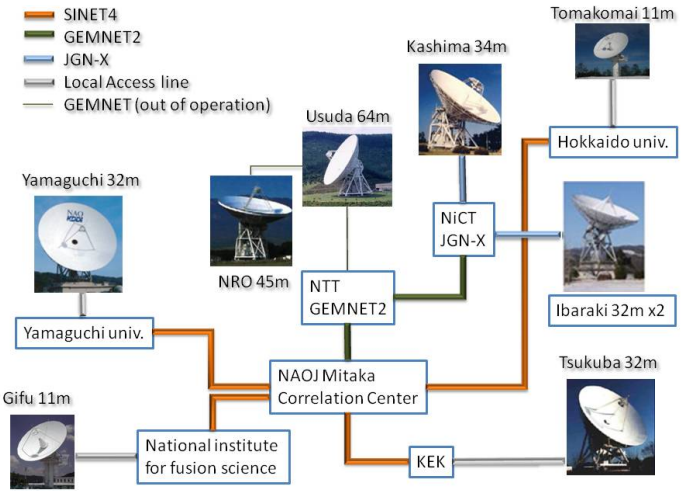


Figure 1. Stations and communication lines of OCTAVE.

OCTAVIA (OCTAve VsI Adapter) is a dedicated module to connect to SINET4 or JGN-X with 10GbE and the VDIF format transmission protocol. VOA-100 is a dedicated device to connect to the local access lines with STM-16 using a dedicated data transmission protocol. OCTAVIA and VOA-100 are equipped with VSI-H ports to enable cross connection of them.

Correlator is also a key module to realize real-time correlation. Two types of dedicated real-time correlators have been developed. One type is an XF-type correlator. Three XF correlators with three baseline processing capability per device have been developed. The input data rate is 2 Gbps per station, and the maximum lag number is 256. The other type is an FX-type correlator. An FX correlator of which the maximum lag number is 16,384 is used for fringe searching and high frequency resolution correlation. Although raw data are not stored for real-time correlation, raw data are stored by HDD recorders for non real-time observations including observations from the Usuda and Nobeyama telescopes. The correlated data are stored in the FITS format.

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